CLASS 9TH(Physics)

FLOATATION

Fluid

Fluid is a substance that flows. For example, liquids and gases. They take the shape of container in which they are stored. The study of fluids at rest is known as hydrostatic or fluid static's. The study of fluids in motion is termed as hydrodynamics.

THRUST

The force acting on the object perpendicular to the surface is called as **thrust**. Thrust is a vector quantity and its unit is same as that of the force i.e. is Newton. Thrust is also expressed in gravitational units called Kgwt (kilogram weight) or kgf (kilogram force). 1 kgwt or 1 kgwf = 9.8 N. Similarly 1 gwt or 1 gf = 980 dyne.

PRESSURE

It is thrust per unit area. Pressure is measure in units of dyne per square cm in C.G.S system and Newton per square metre in S.I system. One Newton per square metre is also known as Pascal (Pa) in honour of French scientist Blaise Pascal.

$$\boldsymbol{Pressure = \frac{Thrust}{Area}}$$

$$\mathbf{P = \frac{F}{A}}$$

$$1\,pa = 1\,\frac{N}{m^2}$$

$$1Nm^{-2} = 10\,dyne\,cm^{-2}$$

The gravitational unit of pressure is kilogram force per square metre which is approximately equal to 10 Pa.

For meteorological purposes the unit of pressure is taken as bar.

1 bar $=10^5$ Pa..

- Pressure in first picture is more as the surface area is less than the surface area in second picture.

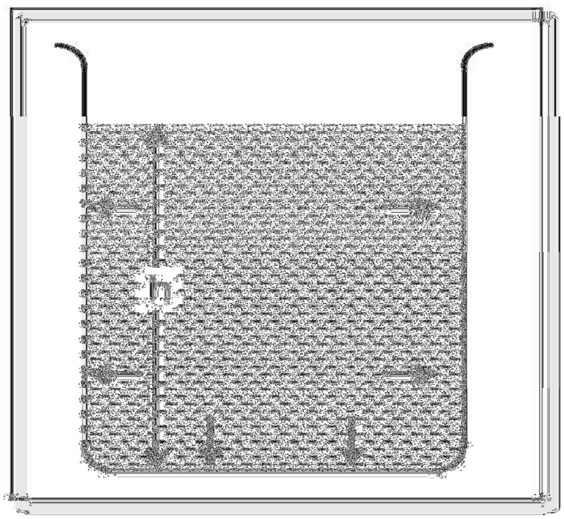
- The same force acting on a smaller area exerts a larger pressure, and a smaller pressure on a larger area.
- This is the reason why a nail has a pointed tip, knives have sharp edges and buildings have wide foundations.
- A school bag has wide straps made of thick canvas. This is done to distribute the entire weight of the bag over a larger area. This in turn will produce a small pressure.

Fluid pressure

It is a measurement of the force per unit area on an object in the fluid or on the surface of a closed container. In a fluid the molecules are in random motion. Due to the random motion they collide among themselves and also with the walls of the container. As the walls of the container are strong on colliding the fluid bounce back. In this process the molecules undergo a change in momentum. The change in momentum of the fluid molecules per second on colliding with walls of the container constitutes a force exerted by the fluid on the walls of its container. This force or thrust per unit area is the pressure exerted by the fluid on the walls of the container.

Mathematical Expression for Fluid Pressure

Consider a liquid of density (ρ) in a beaker upto height (h) as shown the fig.The liquid exerts pressure in all directions. The force exerted on the lateral sides of the beaker by the liquid in all direction at a horizontal level, and thus net force acting on the walls is zero. There is a resultant force exerted on the bottom of the beaker by the liquid. If 'A' is the area of cross section of the beaker and 'F' is the force exerted by the liquid then pressure



$$P = \frac{F}{A}$$

The force 'F' is equal to the weight of the liquid
W=mg.

Density $=\frac{mass}{volume}$

mass= (density) (volume)

mass= (density of liquid) (area of cross section of beaker) (height of liquid column)

mass = ρAh

F=W=mg= (ρAh)g

P= $P = \frac{F}{A}$
P=ρgh
Thus pressure exerted by the liquids depnds at a point inside it is directly proportional to

1. Height of the liquid in the column
2. The density of the liquid
3. Acceleration due to gravity at that place.

UPTHRUST OR BUOYANT FORCE

- When a body is partially or wholly immersed in a liquid, an upward force acts on it.
- This upward force is known as upthrust or buoyant force.
- It is denoted by the symbol F_B.
- Its unit is newton (N) or

Definition of Buoyancy

- The property of a liquid to exert an upward force on a body immersed in it is called buoyancy.
  For example, while pushing a cork into water, our fingers experience the net upward force.
- Like liquids, gases also have the property of buoyancy i.e. a body immersed in a gas also experiences an upthrust.
  For example, a balloon filled with hydrogen rises up because of upthrust.

Effect of Upthrust

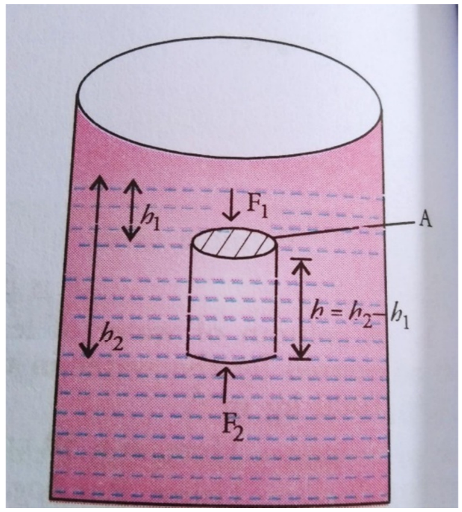
The effect of upthrust is that the weight of the body immersed in a liquid appears to be less than its actual weight.

- Larger the volume of the body submerged in fluid, greater is the upthrust.
- More the density of the fluid, greater is the upthrust.

Expression for Buoyant force or upthrust

Consider a cylindrical object of height 'h' and cross-section area A immersed completely in a liquid of density ' ρ'.

The top surface has area A and is at depth h1



The pressure at that depth is:

$P_1=h_1\rho g$,

where ρ is the density of the fluid and $g\approx 9.81ms^{-2}$ and is the gravitational acceleration. The magnitude of the force on the top surface is:

$F_1=P_1A=h_1\rho gA$ (i).

This force points downwards. Similarly, the force on the bottom surface is:

$F_2=P_2A=h_2\rho gA$ (ii)

and points upwards. Because it is cylindrical, the net force on the object's sides is zero—the forces on different parts of the surface oppose each other and cancel exactly. Thus, the net upward force on the cylinder due to the fluid is:

$F_{net}=F_2-F_1=\rho gA(h_2-h_1)$

H2 – h1=h

But hA= V

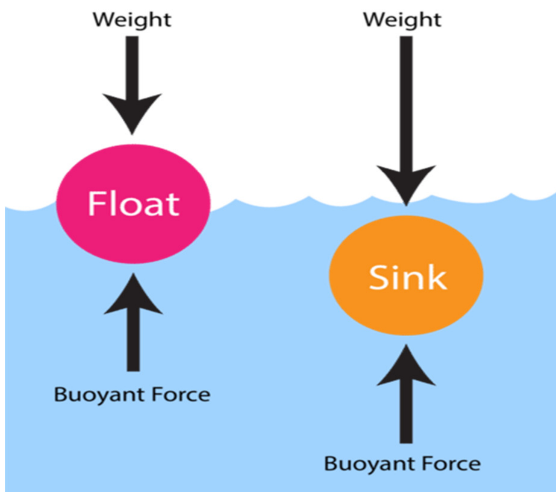
Thus $F_{net} = V\rho g$

This is the expression for the buoyant force where **ρ** is the density of the fluid, V is the volume of the fluid displaced, g is acceleration due to gravity.

Condition for a body to float or sink in fluid

- If $F_B > W$ or $F_B = W$, the body will float.
- If $F_B < W$, the body will sink.
- F_B = upthrust or buoyant force acting vertically upwards.
- W = weight of the body acting vertically downwards.

How will the body float?



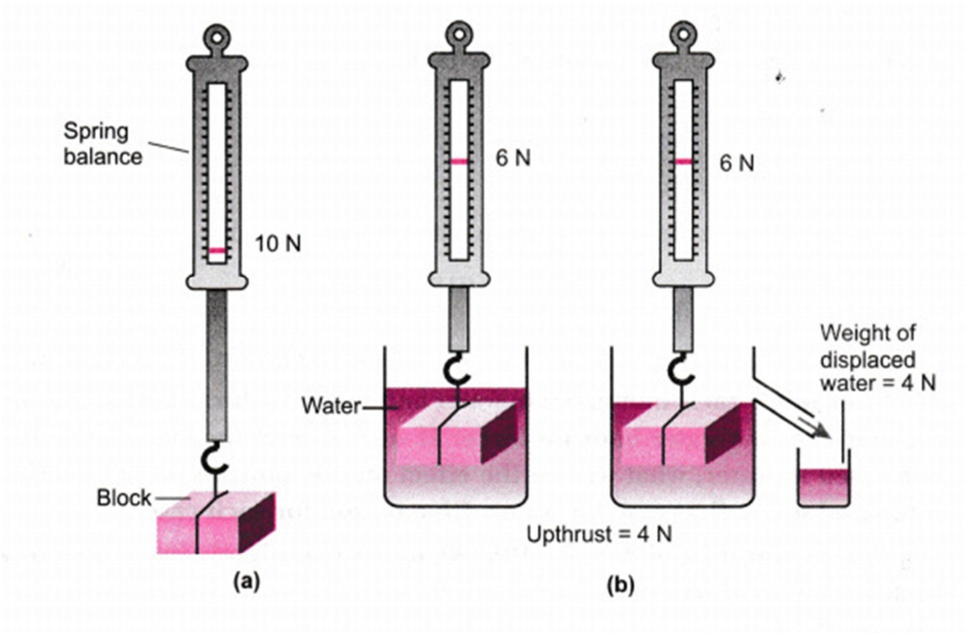
- For $F_B > W$
- The body will float with only that much part (partly immersed) of it inside the liquid, the upthrust due to which becomes equal to the weight of the body.
- For $F_B = W$
- The body will float with the whole of it immersed inside the fluid.
- For a floating body, the net force acting downwards (i.e. apparent weight) is zero.

Archimedes' principle

The Archimedes' principle states that if a body is immersed in a fluid, wholly or partly, then it loses its weight equal to the weight of fluid displaced by the immersed part of the body.

Experimental verification

Take a solid body which is heavier than water and also insoluble in water. Suspend it from the hook of a spring balance to find its weight in air as shown in Fig. (a).



Let its weight in air be W1.

Now take an overflow vessel filled with water up to the overflow mark and place a measuring cylinder below the overflow tube as shown in Fig. (b). Now suspend the given solid from hook to spring balance and lower the solid in the water till it is completely immersed in water.

Note the reading of the spring balance. It gives the weight of solid body in water. Let it be W2.

Loss of weight in solid when immersed in water = W1 - W2.

The water which overflowed when solid was immersed is collected in the cylinder placed below the overflow tube. Measure this volume.
Let it be V

V = Volume of water displaced by the solid immersed in it.
Then weight of water displaced by solid = Vpg
where, p = density of water and g= acceleration due to gravity.
It is found that W1 - W2 loss in weight of solid when immersed in water is equal to the weight of the water displaced by the body. This verifies Archimedes' principle.

Devices based on Archimedes' principle

Design of all those devices which float in the fluid are based on Archimedes' principle. These devices such as hydrometers, lactometers, balloons, boats and ships, submarines, etc., work according to Archimedes' principle.

Relative Density

The density of a substance is defined as its mass per unit volume. $d = m / V$

RELATIVE DENSITY

The relative density of a substance is defined as the ratio of the density of the substance to the density of water at 4°C. It is also known as **specific gravity of the substance**.

$$\text{Relative density (R.D.)} = \frac{\text{Density of substance}}{\text{Density of water at } 4^{\circ}\text{C}} = \frac{\text{mass of any volume of substance}}{\text{mass of same volume of water at } 4^{\circ}\text{C}}$$

Relative density has no unit, since it is the ratio of two similar physical quantities.

Note : Density of every substance is expressed relative to the density of water at 4 °C.

e.g. The density of gold is 19300 kg/m³. The density of water = 1000 kg / m³.

$$\text{Relative density (R.D.) of Gold} = \frac{\text{Density of substance}}{\text{Density of water at } 4^{\circ}\text{C}} = \frac{19300 \text{ kg / m}^3}{1000 \text{ kg / m}^3} = 19.3$$

Relationship Between Density and Relative Density

In C.G.S. system	In S.I. system
$\text{R.D.} = \frac{\text{Density of substance in g cm}^{-3}}{1\text{g cm}^{-3}}$	$\text{R.D.} = \frac{\text{Density of substance in kg m}^{-3}}{1 \text{ kg m}^{-3}}$
Density in g cm^{-3} = Relative density	**Density in kg m^{-3} = Relative density × 1000**

ADDITIONAL QUESTIONS

Q1. Why do we prefer a sharp knife for cutting than a blunt one?

Answer:

The area of a sharp edge is much less than the area of blunt edge. For the same force, pressure is more for sharp edge than the blunt edge. Hence, sharp edge cuts better and easily.

Q2. The volume of 50 g of a substance is 20 cm^3. If the density of water is 1 g cm^{-3}, will the substance float or sink? Justify your answer.

Answer:

Volume = 20 cm^3, Mass = 50 g

$$\therefore \quad \text{Density of substance} = \frac{\text{Mass}}{\text{Volume}} = \frac{50 \text{ g}}{20 \text{ cm}^3} = 2{\cdot}5 \text{ g cm}^{-3}$$

Since density of substance is more than the density of water, so the substance will sink.

Q3. The volume of a 500 g sealed packet is 350 cm^3. Will the packet float or sink in water if density of water is 1 g cm^{-3}? What wall be the mass of the water displaced by the packet?

Answer:

Mass = 500 g, Volume = 350 cm^3

$$\therefore \quad \text{Density of packet} = \frac{\text{Mass}}{\text{Volume}} = \frac{500 \text{ g}}{350 \text{ cm}^3}$$

Q4. Relative density of aluminium is 2.7. Explain this statement.

Answer:

Aluminium is 2.7 times heavier than the equal volume of water.

Q5. Why does an iron nail sinks in water but a wooden cork floats on water?

Answer:

The weight of iron is greater than the upthrust of water on the iron nail, so iron nail sinks in water. On the other hand, the upthrust on cork is more than the weight of the cork. Hence wooden cork floats on water.

Q6. An egg sinks in fresh water but floats in highly salty water. Give reason.

Answer:

Upthrust acting on egg in fresh water is less than the weight of egg. Therefore, it sinks in fresh water. However, the density of salty water is much greater than the density of fresh water, so upthrust acting on egg in salty water is greater than the weight of egg. Therefore, it floats in salty water.